ECOROOFS (GREENROOFS) – A MORE SUSTAINABLE INFRASTRUCTURE

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Abstract

All cities have two primary impervious elements; rooftops and pavement. These usually represent an extensive network of imperviousness and make up about 45% of the surface area of a city at full build out. The results of this imperviousness have been documented in a number of papers, but the main environmental effects include increased destabilization of streams and increased runoff pollutant loadings and concentrations. To address stormwater concerns and to provide other environmental benefits, the City of Portland has developed a program to encourage the use of EcoRoofs (vegetated roofs). This paper will present the overall City program, including a discussion of the incentives and assistance the City provides to encourage development projects to employ green roofs. The paper will review some of the installations that have occurred and discuss some of the practical lessons that have been learned regarding green roofs.

The City has also been monitoring runoff from several EcoRoofs in an attempt to ascertain the water quantity and quality performance of the roofs in slowing down or eliminating runoff, as well as associated pollutant loads and concentrations. The monitoring has included the installation of rooftop rain gages and flow measurement devices. Water quality samples are also collected. One roof has had two different depths of soil layers (2" and 4") employed with separate flow monitoring gages for each. The paper presents hydrological results for selected storm events on a seasonal basis, as well as initial water quality results.

Introduction

The elements of urban development are similar throughout the United States. Homes, apartments, commercial and industrial sites and the supporting transportation systems cover the land in varying densities. Large areas of impervious surface in the form of rooftops and pavement have been placed on the land, wetlands, and even creeks. However, the ideal conditions for salmon, and other wildlife of the Pacific Northwest are predominately an evergreen (coniferous) forest and its associated functions with clean cool rivers and streams. The results of this imperviousness have been documented in a number of papers, but the main environmental effects include increased destabilization of streams and increased runoff pollutant loadings and concentrations (May et. al., 1997). Since these impervious urban elements are essential to human communities, what can be done to mitigate their negative impacts? In Portland, we are implementing new design techniques, which include EcoRoofs (living vegetated roof ecosystems), pervious pavements, landscape planters and swales, infiltration gardens, watergardens, vertical landscaping, and trees. The techniques are applicable to new and re-development, and to retrofitting existing development. The focus of this paper is on the 'EcoRoof' and its potential for reducing the impacts of urbanization.

What is an EcoRoof?

An EcoRoof is a living vegetated ecosystem of lightweight soil and self-sustaining vegetation. It is biologically ‘alive’ and as such provides a protective cover on the building by using the natural elements of sun, wind, and rain to sustain itself. This protective cover allows the waterproof membrane to last for as long as 30-40 years or more. The EcoRoof requires little maintenance and provides an aesthetic alternative, with economic and ecological attributes not found in a conventional roof. The main components include a waterproof membrane or material that prevents water from entering the building; drainage material such as geotextile webbing that allows water to flow to the drains when the substrate is saturated; and soil or substrate (growing medium) as light as 6 pounds per square foot (psf). To date in Portland, the lightest weight substrate used is at Hamilton Apartments at 10 psf saturated, at a 3-inch depth. Selection of vegetation or plant materials can range from mosses, lichens and ferns, to sedums and other succulents, to grasses, herbs and ground covers. Irrigation requirements are very much affected by the plants selection. Sedums and succulents appear to be the mainstay of least water dependent plants, based on experience in Portland. Figure 1 shows the Hamilton Apartments EcoRoof.

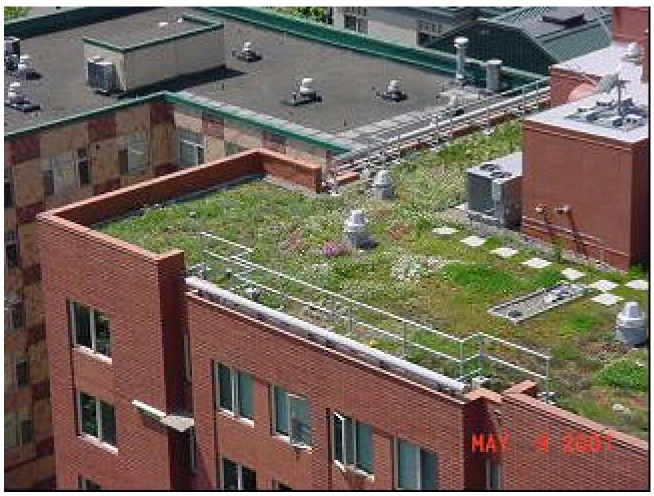

Figure 1. Aerial view of a vegetated EcoRoof on Hamilton Apartments in downtown Portland.

A traditional Roof Garden (see example in Figure 2, left photo) by comparison usually requires more substantial structural building upgrade and is made up of heavy soils and vegetation, often including trees, and requires significantly more irrigation and maintenance. Roof gardens may cover only a small percentage of the roof surface and usually have paved terraces for people to use. Although they do provide some benefits not found with the use of conventional roofs, they do not provide the benefits as an EcoRoof. They also are generally much more expensive to build and maintain than conventional roofs. EcoRoofs are more comparable in cost to standard roofs.

Another type of vegetated roof is an ag-roof (see example in Figure 2, right photo). Some building owners are finding it advantageous to grow crops on their rooftops. One such Portlander harvests hundreds of pounds of tomatoes each week.

The City of Portland decided to use the term ‘EcoRoof’ to describe their “green” roof program for several reasons. First, the western United States including most of Oregon and Washington has dry warmer seasons and may not receive precipitation for many months. Native plants although more self-sustaining often do not remain "green." Thus a "not green" or brown roof does not imply that the vegetation has died, thus the prefix eco (for ecosystem) was chosen as being more descriptive of what the roofs are intended to achieve. . Another reason was the many references to the economic value, especially the longer life, thus eco also refers to the economic benefits.


Figure 2. An aerial view of a typical Roof Garden in downtown Portland and Doug Christie and Cameron Hyde atop Doug's ag-roof in Portland with crops shown.

What Do EcoRoofs Do?

Based upon an evaluation of hydrological, energy, and other principals and monitoring data produced thus far in Portland, EcoRoofs appear to be able to address many environmental and economic issues. The City's original interest was stormwater management, but has since broadened to consideration of other EcoRoof attributes. Precipitation that lands on an EcoRoof acts in the following ways. Portions of it are intercepted by vegetation and then evaporate; portions are absorbed in the soil; portions in the soil are taken into the vegetation and then transpire; some water evaporates from the soil; and excess amounts flow through the soil and become runoff. These characteristics are highly affected by seasonal conditions. Interception, evaporation, and transpiration act to prevent runoff and can be lumped into one term, rainfall retention. This portion of the rain never turns into runoff. One of the primary objectives of the monitoring program has been to assess the effectiveness of EcoRoofs in reducing the volume of runoff. Some water quality monitoring has also been performed to assess the potential for reduced as well as added pollutants in the runoff that does occur. Finally, the hydrology and water quality results have been employed to assess potential reductions in pollutant loads. Table 1 provides a comparison of EcoRoofs environmental and other characteristics to conventional roofs. Note that the conventional roof is often the cause of the problem being addressed.

The Portland EcoRoof Experience

Portland has a total area of 135 square miles. Although rooftops constitute only one type of surfacing, they represent about 40% of all impervious surfaces in the city. At full build-out based on current zoning, rooftops are likely to cover more than 25 square miles of the city. However, if zoning densities increase over the coming decades the city roof area could be much larger.

Table 1. A Comparison of Environmental and Other Characteristics of EcoRoofs and Conventional roofs.

Subject	EcoRoof	Conventional Roof
Stormwater		
Volume retention	10-35% during wet season, 65-100% during dry season	None
Peak flow mitigation	All storms reduced runoff peaks	None
Temperature mitigation	All storms	None
Improved water quality	Retains atmospheric deposition and retards roof material degradation, reduced volumes reduce pollutant loadings	No
Air quality	Filters air, prevents temperature increases, stores carbon	None
Energy Conservation	Insulates buildings, reduces Urban Heat Island impacts	None
Vegetation	Allows seasonal evapotranspiration; provides photosynthesis, oxygen, carbon water balance	None
Green Space	Replaces green space lost to building footprint:, although not equal to a forest	None
Zoning floor area bonus	3 ft^2 added floor area ratio (FAR) for each EcoRoof ft^2 when building cover over 60%	None
City Drainage fee reduction	To be determined, may be up to 45%	None
Approved as stormwater management	For all current city requirements	No
Habitat	For insects and birds	None
Livability	Buffers noise, eliminates glare, alternative aesthetic, offers passive recreation	None
Costs	Highly variable from \$5-\$12 ft^2 new construction and \$7 - \$20 ft^2 retrofits	Highly variable from \$2-\$10 ft^2 new construction and \$4 -\$15 ft^2 retrofits
Cost off-sets	Reduced stormwater facilities, energy savings, higher rental value, increase property values, reduced need for insulation materials, reduces waste to landfill, creates jobs and industry	None
Durability	Waterproof membrane protected from solar and temperature exposure lasts more than 36 years, membrane protected from O&M staff damage	Little protection, exposure to elements, lasts less than 20 years

In 1991 the city of Portland was required by US Environmental Protection Agency and the Oregon Department of Environmental Quality to begin more aggressive programs to reduce pollutants in stormwater discharges and abate combined sewer overflows. Both of these problems have as their common cause urbanization. The traditional solutions that Portland began to implement, included the use of end-of-pipe treatment such as ponds to treat stormwater flows and large pipes and underground storage systems to address combined sewerage overflows. The City did embark on a program to "Start at the Source" using such techniques as roof drain disconnect programs in combined areas of the City. Portland first began to consider EcoRoofs in 1995 . The technique seemed to fit the concept of creating something that would be more like nature, absorbing and then slowly releasing moisture through evapotranspiration and low flows, thus providing precipitation retention and stormwater management. The City began to ask if this could be a way to reduce or control CSOs and reduce the erosive scouring forces of runoff in streams. Many people in the city were intrigued with the possibilities and investigative efforts began in earnest.

Milestones in Portland's EcoRoof Program

The following presents a brief summary of the milestones in the development and implementation of the City's EcoRoof program:

- 1996 -- First EcoRoof installed on a residential garage, stormwater monitoring was conducted for 27 months from 1997 -1999
- 1997 – Bureau of Environmental Services (BES) and Portland General Electric (PGE) assisted Portland State University planning students with a study on roof gardens. A report was produced.
- 1997 - BES built a small EcoRoof shelter at the Portland Home and Garden Show. Survey of over 600 visitors was 75% favorable.
- 1998 -- BES and PGE provide grant funding of a 300 ft^2 EcoRoof installation on an apartment building. This would be the first use of BES Community Watershed Stewardship Program grants for an EcoRoof.
- 1998 -- BES begins to offer limited technical assistance to developers who consider EcoRoofs.
- 1999 -- A city worker is interviewed on the NRP 'Living on Earth' show and receives encouraging phone calls from around the country.
- 1999 -- Almost simultaneously two projects, with different owners, request BES assistance to install EcoRoofs.
- July, 1999 -- The EcoRoof is officially recognized as a stormwater management technique and is included in the city's Stormwater Management Manual.
- September, 1999 -- Hamilton Apartments EcoRoofs are completed.
- March 2000 -- Buckman Terrace mixed-use building EcoRoofs are completed.
- Early 2001 -- BES began measuring precipitation and runoff at the Hamilton. However the efforts were plagued with technical problems. In December, 2001, problems are corrected. Subsequent flow data not only supports the monitoring results of the garage data, but also shows better performance.

- 2001 -- BES begins work on a drainage fee discount for installation of EcoRoofs or other green approaches. (This work has been delayed and the discount is not expected to be available till 2004).
- 2001 -- Two small EcoRoof shelters are completed at nature areas.
- March, 2001 -- The city zoning code is amended to include EcoRoofs as a floor area bonus option. Property owners can add up to 3 ft^2 of floor area for every ft^2 of EcoRoof if the EcoRoof covers at least 60% of the rooftop. Less area is granted if the % coverage is less than 60%.
- 2001 -- BES offers potentially $30,000 grants for EcoRoofs (or other green techniques) in a portion of the combined sewer area. Two roof retrofits were considered and one is approved for funding.
- 2001 -- Mosaic Condominiums apply for EcoRoof bonus and get enough ft^2 to add six additional condominiums to the building.
- September, 2001 -- Ecotrust building EcoRoof completed.
- October, 2001-- BES and the City's Office of Sustainable Development convene a City EcoRoof Forum. An overwhelming majority of attendees supported the EcoRoofs concept. Three major issues are identified: need more cost-comparative information, need incentives at the early stages, and need technical assistance.
- December, 2001 -- BES installs an EcoRoof on a portion of the it's wastewater treatment plant.
- 2002 -- BES completes an EcoRoof Question and Answer brochure and posts it on its web site.
- July 2002 -- Fire Station #12 EcoRoof is constructed.
- 2002 -- Mosaic condos begin construction.

Portland EcoRoof Monitoring

The City of Portland has been active in implementing monitoring programs to assess the effectiveness of the EcoRoof in reducing impacts to downstream receiving waters as well as reducing CSO impacts. This section presents a brief overview of the two monitoring projects that the City has been conducting.

Residential Garage EcoRoof Monitoring

An EcoRoof was installed on a structure shown (Figure 3) in October 1996 . The building structure was upgraded and a waterproof membrane was applied over the existing composite rollout shingles. Two to three inches of topsoil and compost mix were applied and planted with seven species of sedum. Grass has also grown on its own with what appears to be four predominate species. The EcoRoof is 180 ft^2 and has about a 7% slope toward the east. About half of the roof has full solar exposure and the other half is partially shaded. Figure 3 shows the EcoRoof in late spring 2002.

Figure 3. View of a residential garage EcoRoof that was monitored for a two-year period.

BES monitored rainfall retention of the garage EcoRoof from August of 1997 until October of 1999. A rain gage was installed on the EcoRoof and the roof downspout was connected to two tanks with a total capacity of 78 gallons. A spreadsheet was created to record the rainfall, runoff and retention. The rain gage and tanks were checked every morning and evening during storm events. Any flow in the tanks represented runoff and the difference between rainfall and runoff was the retention. Figure 4 shows the precipitation retention for the 27-month period. Figure 5 show the results of a rainfall simulation test to identify how peak flows might be attenuated. In the test, a large volume of water was applied to the roof and then the recorded runoff was compared to this volume. Water was applied with a garden hose and before each application the flow from the hose was measured and recorded.

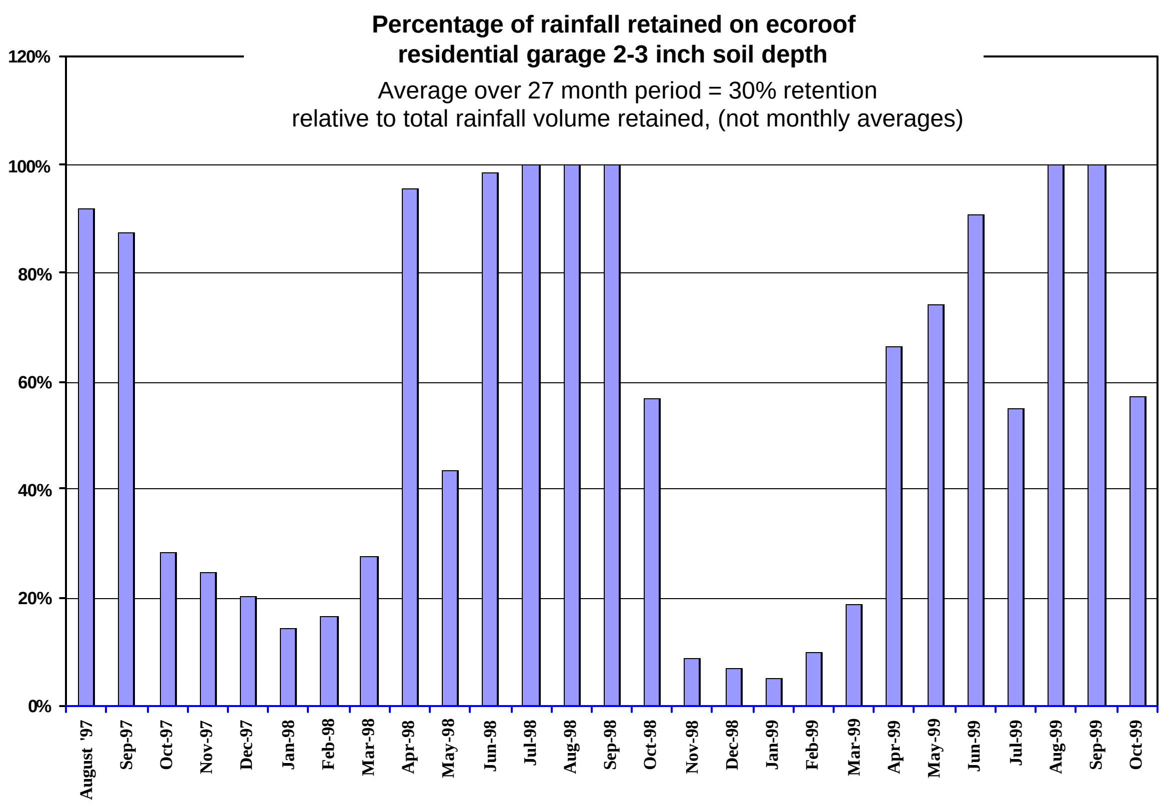

Figure 4. Chart showing the month-by-month percentage of rainfall retained on a residential garage roof in Portland.

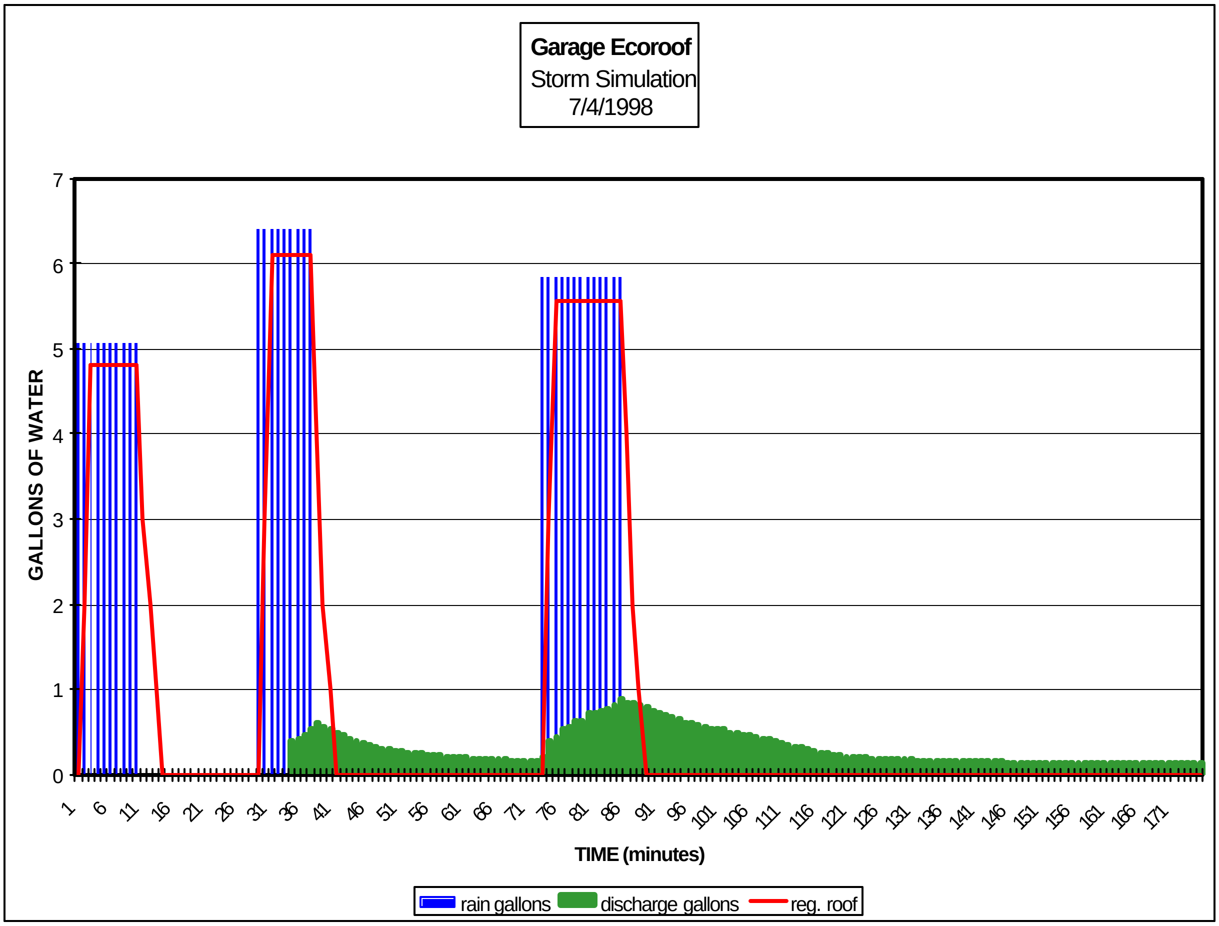

Figure 5. Chart showing gallons of water introduced to a residential EcoRoof and the much lower number of gallons that ran off, as well as much lower peak flows.

The percentage of retention on this roof on a monthly basis during the study period, has ranged from <10% in Jan 1999, with 11 in. of rainfall and up to 100% in the dry season months. For the rainfall volume for the two-year period, the average annual retention was about 28%. Rainfall during this two-year period was 99 in. or 33% more than the average two-year total of 74 in. Higher than average rainfall and the fact that the EcoRoof is partially shaded in spring, fall and winter would have reduced evaporation and thus reduce the retention performance. The simulated storm demonstrated how the EcoRoof could attenuate a large storm under dry season conditions. The most sensitive stream conditions often occur when a larger warm weather storm occurs.

Hamilton Apartments EcoRoofs Monitoring

The Hamilton Apartment Building (Figure 1) in downtown Portland is the site of a more comprehensive monitoring effort by the City. The Housing Authority of Portland, in cooperation with the City of Portland's Bureau of Environmental Services (BES), built the Hamilton Apartments Building EcoRoofs in the autumn of 1999. Over 75 species of plants were installed in an identical arrangement on each side of the building. Three different mechanisms were used to plant the vegetation, plugs, hydroseed, and mats. The idea was to gain some understanding of which plants would do the best and what type of planting would provide the best growth and coverage. An irrigation system was installed. BES is testing to determine characteristics of planting methods, measurement of runoff flows and precipitation, and viability of soil and vegetation. Insects and birds are also being monitored to a very limited extent. Garland Co. waterproof membrane and planting design was used on this project. Figure 6 shows various views of the EcoRoofs.

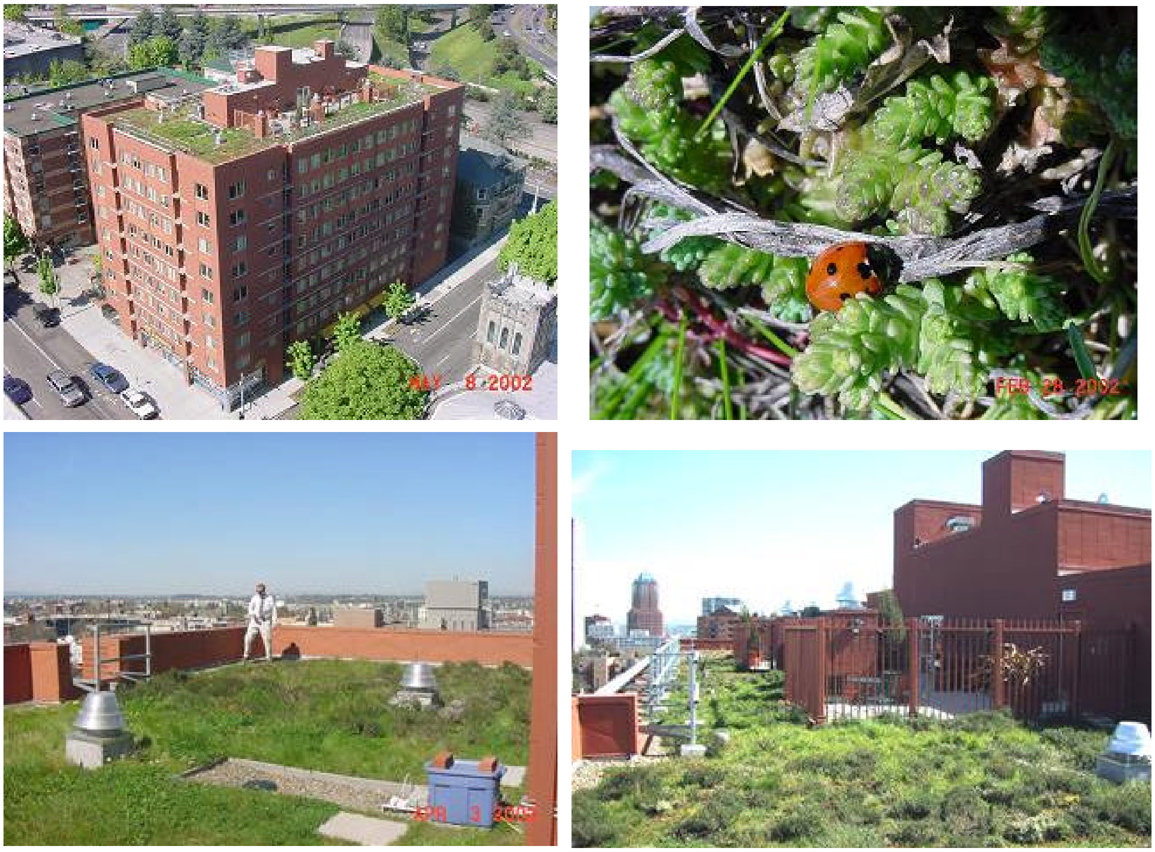

Figure 6. Photographs of the Hamilton EcoRoof, including an aerial photo from above, a close-up of vegetation and a ladybug, and two pictures of the roof from the roof; one showing the area of the roof where access is restricted and the other including the patio area behind a fence.

There are two drains on the building: an east drain has a 3,848 ft^2 catchment with 2,620 ft^2 of EcoRoof area and the west drain has a 3,690 ft^2 catchment with 2,520 ft^2 of EcoRoof area. All other surfaces are vents, parapet walls, gravel, and terrace paved areas. All monitoring is relative to these other surface contributions and implies that a 100% EcoRoof would have improved precipitation management. The conventional roof runoff has been disconnected from the EcoRoofs, but the terrace areas drain to each of the EcoRoof drains through the substrate. In both cases, the catchments are about 75% EcoRoof and 25 % hard surfaces.

The drainage from the EcoRoof was split in half for research purposes. The west half has a four to five inch soil which weighs 20-25 lbs/ft^2 and the east half has a two-three inch soil weighing 7-10 lbs/ft^2 when saturated. The east soil is composed of digested fiber, encapsulated styrofoam, perlite, peat moss and compost. The west soil consists of digested fiber, compost, perlite and topsoil. Figure 7 shows the chemical composition of the two substrates utilized. In general, the Westside soil mixture appears to have higher concentrations of heavy metals and nutrients. As rain falls and soaks into the soil it flows to the roof drains located at each end of the building where a monitoring station collects flow data prior to entering the piped system. There is an additional roof drain with a two-inch collar in case the monitoring equipment or the main roof drain was to become plugged.

Figure 7 Hamilton EcoRoof Substrate (soil) Composition

Parameter	Extractant	Method Number	Unit	Eastside	Westside	Ratio
Total As		EPA 200.9	mg/kg	4.54	2.19	0.5
Total Cu		EPA 200.7	mg/kg	17.5	30.3	1.7
Total Pb		EPA 200.9	mg/kg	5.57	64.9	11.7
Total Zn		EPA 200.7	mg/kg	48.2	146.1	3.0
Extractable As	DTPA	EPA 200.9	mg/kg	0.01	0.09	9.0
Extractable Cu	DTPA	EPA 200.7	mg/kg	1.25	6.08	4.9
Extractable Pb	DTPA	EPA 200.9	mg/kg	0.26	2.43	9.3
Extractable Zn	DTPA	EPA 200.7	mg/kg	4.9	64.8	13.2
Extractable NO3-N	1 N KCl	SM 4500-NO3 F	mg/kg	253.6	798.3	3.1
Extractable NH4-N	1 N KCl	SM 4500-NH4	mg/kg	2.7	28.6	10.6
TKN		EPA 351.4	mg/kg	1897	12802	6.7
Total Phosphorus		EPA 200.7	mg/kg	958	2508	2.6
Extractable PO4-P	0.5 N NaHCO3	SM 4500 P E	mg/kg	100	325	3.3

Equipment

Flow monitoring equipment includes a small 60-degree, V-trapezoidal Plasti-Fab flume, and a hydraulic bubbler-type flow meter, which measures the water level in the flume as shown in Figure 8 . The flumes were custom made to attach to the two main drainage points. This data is instantaneously transmitted to the BES Lab where it is converted and stored on the BES computer network.

BES has been testing another type of flow monitoring equipment. It is a small mobile Sigma flow meter, Model 950, configured with a bubbler-type level sensor. It appears very small flow levels can be captured with this type of meter. Data is stored in a mobile data logger. Figure 8 shows a BES staff installing the added equipment. Figure 8 also shows the flume with the bubbler tubes, one connected to the data logger and the other connected to a transducer that telemetrically sends flow and rainfall data directly to the lab.

A rain gauge was installed on the building to ensure that accurate rain data is collected for the site. This data is collected and stored, then accessed via computer on the city network.

Figure 8 . Two photographs of one of the monitoring stations. One shows the data logger and bubbler with the flume and the second is a close-up of the flume.

Flow Monitoring

Initially BES had a lot of problems with the flow meters, but has since corrected these problems and added the two new meters. Currently each drain has two meters and both are showing comparable results. All data collected since December, 2001 is considered good. The graphs represent 75 % EcoRoof and 25 % impervious. Figure 9 shows the runoff associated with the long duration winter storm event and the slow release water that cannot be retained in the saturated substrate. Note the mitigation of the peak intensities of the event. Figure 10 shows the almost complete retention of a typical Portland summer storm. The estimated runoff from a conventional roof surface would be very similar to the rainfall lines as the rainfall would almost immediately turn to runoff as the rain occurs. An almost ¾ in. storm was mostly retained on a roof with 4 in. of soil.

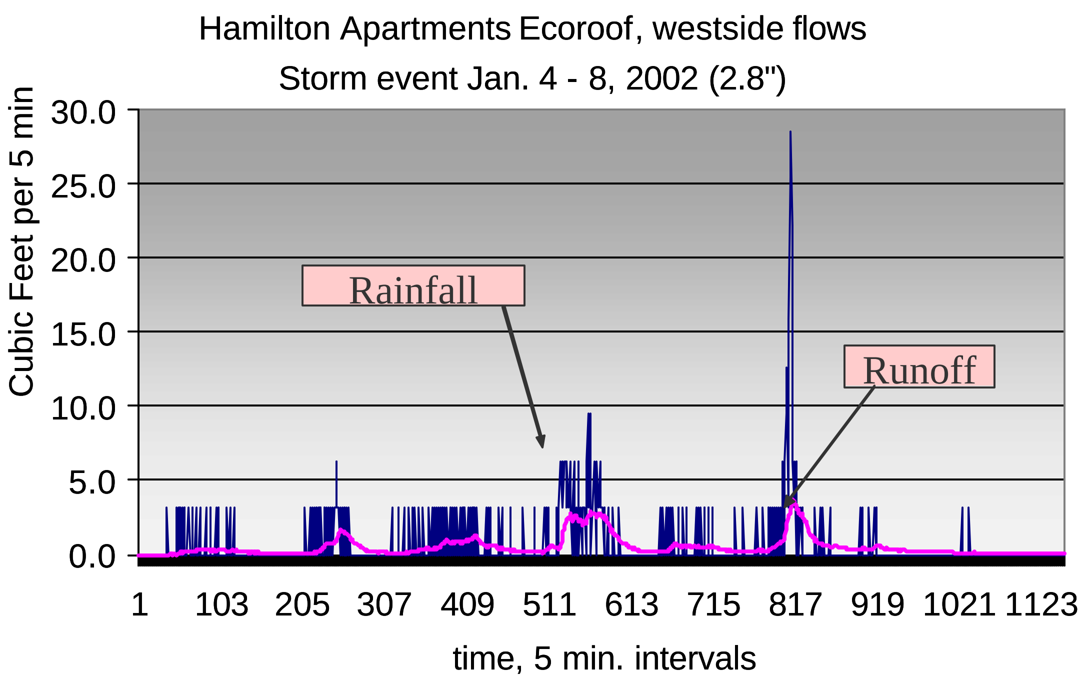

Figure 9. A chart of measured Hamilton Apartment EcoRoof Westside (2 in. soils) rainfall versus runoff, in units of cubic feet per 5 minutes versus 5-minute time increments showing the reduction in runoff volumes and peaks for a winter storm.

Water Quality Monitoring

To date, five storms have been monitored for water quality. The results are encouraging, but also show how attention to substrate chemical composition may be needed (see Figure 7) depending on the receiving water system.

Sampling Procedures

BES Field Operations staff performed sample collection and field parameter readings. The BES Laboratory section performed the analytical testing. The minimum storm criteria for water quality analysis for this project was 0.25 inches of rain in 24 hours to ensure runoff volumes are sufficient. Grab samples were collected at the middle to latter part of the storms. The water quality grab samples were collected at the termination of the flumes using a decontaminated stainless steel bailer or the sample container directly.

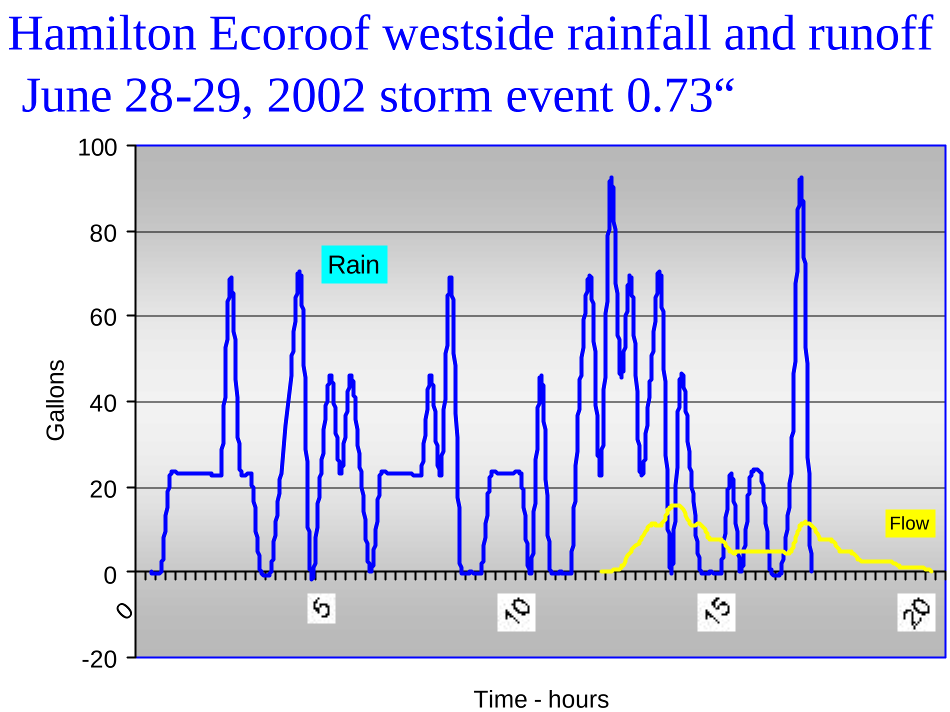

Figure 10 . Measured Hamilton Apartment EcoRoof Westside (4 in. soils) rainfall versus runoff in units of gallons-per-hour versus time in hourly increments, showing the significant reduction in runoff volumes and peaks for a summer storm.

Analytical Parameters
Samples were analyzed in the field for dissolved oxygen, pH, specific conductance, and temperature using portable field meters. Samples were submitted to the laboratory for analysis of ammonia-nitrogen, biochemical oxygen demand, chemical oxygen demand, color, total and dissolved metals (arsenic, cadmium, copper, lead, silver, and zinc), *Escherichia coli,* orthophosphate-phosphorus, total phosphorus, and total suspended and dissolved solids.

Figures 11 and 12 show constituents such as Total Phosphorous and Ortho-phosphorous at concentrations above receiving water standards. Note the difference between Eastside and Westside flow concentrations and the substrate chemical composition shown in Figure 7. It appeared that over time phosphorus levels might be coming down, but there was a spike in one of the samples in the last storm. We believe that the phosphorus issue can be corrected by being careful to specify a substrate, which would not allow excessive amounts of TP to release from the soil or in fact one that might tend to retain phosphorus. Another issue is the contribution of certain constituents from the terrace area. Numerous activities occur with lots of food, drinks, fireworks, dogs and many other pollutant sources. Obviously these sources may affect some of the characteristics of the water quality due to human and other impacts**.** One important lesson to date is that these sources should be addressed in monitoring studies, either by conducting studies where they do not exist or by education efforts**.** This is the only EcoRoof the City is monitoring for water quality at this time; others will be monitored in the future.

Another important characteristic is the EcoRoof affect on loadings. As shown above, many storm events, especially the warm season storms, significantly reduce flow volumes, thus reducing loadings. And in many cases the flow is zero with zero concentrations, particularly during the drier times of year.

Figure 13 shows dissolved copper concentrations which, based on water hardness, are usually below in-stream standards. Again attention to substrate ingredients and materials to be used on the roof can affect these parameters. For example, the roofing industry uses lots of galvanized metals, copper and lead. It is unknown whether the wood was treated with copper, a potential source for copper on the Hamilton building was treated lumber the landscape contractor used for edging material. However, as pointed out above, the copper loadings would be much reduced as compared to a traditional roof. One option that should be evaluated in reducing pollution from all roofs is the types of roofing materials that are allowed. Several projects in Southern California (Crystal Cove, Newport Beach for example) have restrictions on copper and zinc containing materials being used for roofs, gutters, and downspouts.

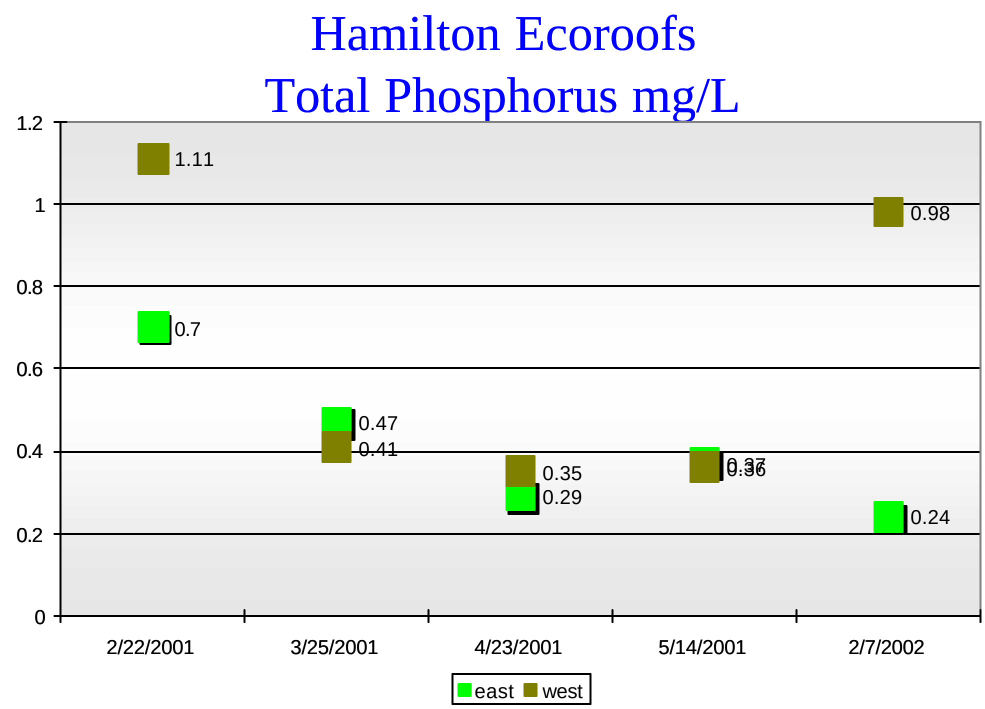

Figure 11. A chart of showing the total phosphorus concentrations measured in roof runoff from both the east and west roof areas. There is a deceasing trend in phosphorus concentrations with the exception of the west roof's last sample.

What else have we learned?

Almost an inch of soil was lost to wind erosion, especially on the east side. The initial planting did not provide good vegetative cover in all areas, which could have protected against this erosion. Depending on the initial planting scheme, cover crops such as common clover may provide excellent soil coverage. Water from air conditioning condensate is a possible source of free, non-potable water for irrigation. Condensate flows were significant during the hottest part of the summer, with flows measured at 12 oz.-per minute in the afternoon and 6 oz.-per minute in the late evening. This might prove to be a free source of irrigation water, if considered during the design phase. Mosses have populated certain areas of exposed soil and helped reduce wind and soil erosion. Lightweight soils must be fully covered to prevent erosion. The eastside is now only about 2 in. thick and the west side is about 4 in. thick. A small colony of ladybugs has been observed in the south half of the eastside and numerous other insects. Hummingbirds, blue jays, crows, swallows, pigeons, sparrows, and signs of hawks or owls have been observed.

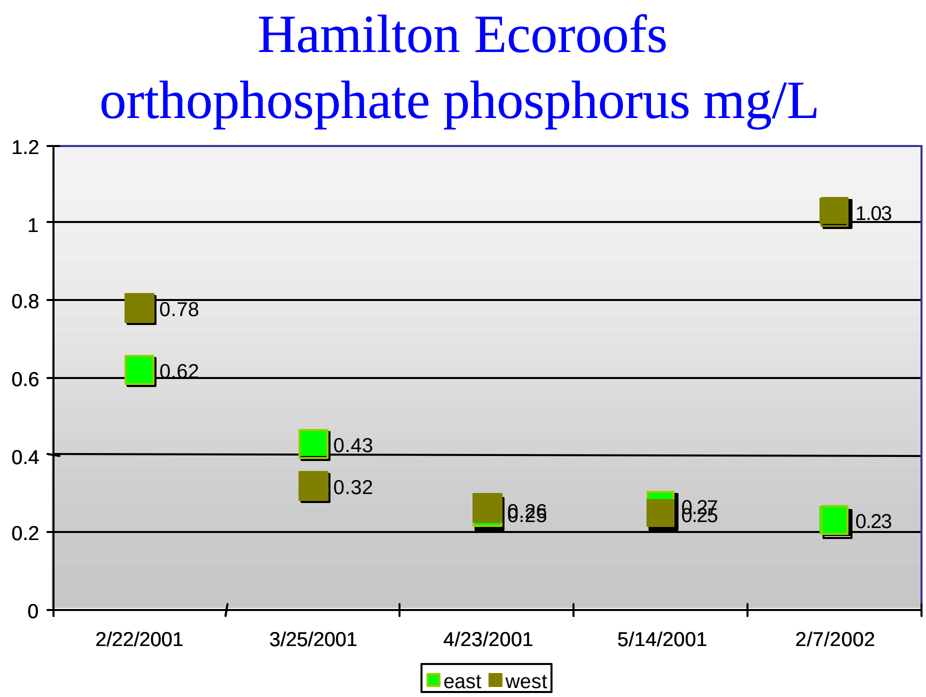

Figure 12. A chart of showing the orthophosphate concentrations measured in roof runoff from both the east and west roof areas. There is a deceasing trend in phosphorus concentrations with the exception of the west roof's last sample.

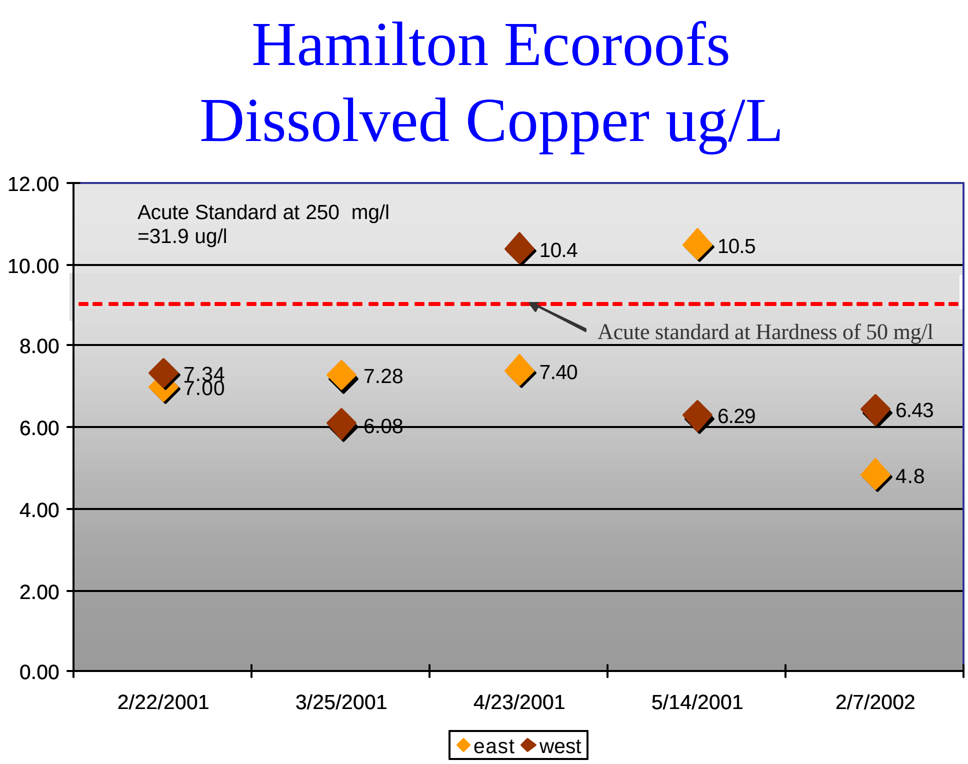

Figure 13. A chart of showing the dissolved copper concentrations measured in roof runoff from both the east and west roof areas. Most samples (8 of 10) were below acute water quality criteria at a hardness of 50 mg/l.

Soil and Vegetation Monitoring

As a part of our monitoring the city is photo documenting the EcoRoof vegetation on a regular basis in addition to documenting changes and problems with the soil. The vegetation has gone through seasonal changes yet has continued to grow and cover the soil. Some problems have included volunteer grasses, plants and clover. The volunteer plants alone are not a large problem since in most cases they will not live through the summer without irrigation.

Air Temperature

In addition to stormwater monitoring discussed above, some energy-related measurements have been conducted. For example, the City has been comparing inside and outside temperatures of the garage EcoRoof and found that EcoRoofs appear to provide cooling benefits**.** There is no insulation on the garage except for the EcoRoof.

Demonstrations and Incentives

The BES has provided incremental funding for three projects to date, but not the residential garage. Funds are obtained from BES sewer and stormwater revenues. The rationale for public funds being used is that these projects will help the City determine the stormwater and CSO management values of EcoRoofs. In addition, the City now allows builders to exceed building height restrictions with the implementation of a EcoRoof. In addition, there is a stewardship grant program which, to date, has provided funding for four projects. In the future, credits on stormwater utility fees will also likely be put in place. Finally, the EcoRoof can be used to meet or partially meet stormwater treatment requirements.

Other Lessons – Buckman Terrace

Buckman Terrace is a redevelopment project by Prendergast Associates. The project was designed in 1998 and opened in 2000. This is a 0.8-acre site with 150 apartment units, with all below-building parking and a 1,500 ft^2 commercial section in a 4-story structure. The building also has car sharing and numerous other environmental attributes.

The entire building has a roof area of approximately 25,000 ft^2 and is constructed with sufficient structural capacity to hold an EcoRoof. As a test, EcoRoofs were placed on two sections. Figure 14 shows the main EcoRoof, which comprises over 1,500 ft^2 of commercial space that has full solar exposure. An additional 750 ft^2 of impervious roof area drains onto this south facing EcoRoof. Figure 15 shows the entrance EcoRoof, which is also planted with sword fern, licorice fern and white stonecrop. It is on the eastside and is in the shade of a north-facing wall. Both were planted in March 2000. The main EcoRoof was planted with two species of Oregon sedum, various wildflowers, native grasses and a few licorice ferns. Grasses and wildflowers were planted from seed and mulch was hand broadcast to protect against wind erosion. An irrigation system has not been installed for either EcoRoof. The soil profile is 4 in. deep and 20 lbs ft^2 when saturated. American Hydrotech waterproof membrane and reservoir drain system was used. BES staff specified the soil mix and vegetation.

While the grasses and wildflowers achieved a graceful, flowing appearance, they are reminiscent of an Eastern Oregon or Midwestern American prairie. Since residents who would rather have a “greener look,” for the EcoRoof, the roof is going to be replanted. The Fire Department was also concerned about the dry grasses, which is an important issue for EcoRoofs without irrigation systems.

During the warm season, storm event runoff was visually observed to be very low or non-existent. The EcoRoof has capacity to hold much of the additional flow from the other roofs. During winter storms, runoff occurs often, but it is detained and released slowly. Many of the plants survived or re-seeded themselves with only one hand-watering. Although no maintenance was conducted this last year, it appears the grasses will need to be mowed at least once a year.

Figure 14. Two photographs of the Buckman Terrace EcoRoof showing uses of grasses and wildflowers.

Figure 15. Buckman Terrace EcoRoof at the building entry with protection from north facing wall

Summary

In initial sampling, EcoRoofs have been shown to significantly reduce runoff volumes, especially in spring, summer, and fall. They also help to slow runoff during winter periods.

In addition it appears that water quality could be significantly improved via loadings (volume) reduction as well as pollutant removal/avoidance. Additional monitoring data on EcoRoof water quality will be conducted by the city to assess the benefits of concentration reductions, and the loading reductions from reducing runoff amounts. There is a need to be strategic about the selection of soils/growing media to use on EcoRoofs as some soils may contain higher levels of pollutants. In addition other roof materials, such as treated woods need to be avoided.

Developers in Portland are gaining confidence in the value of EcoRoofs, as more and more builders gain experience with EcoRoof design and construction. The City allows developers to meet or partially meet their stormwater treatment requirements with an EcoRoof. In dense urban situations, this has become more and more attractive to developers. In addition the City allows taller buildings as an incentive. In the future, there will be a potential reduction in stormwater fees via a reduced fee for those sites with EcoRoofs. One of the primary reasons that developers are embracing the program is the City's technical and permitting assistance provided by the Bureau of Environmental Services.

As with any stormwater management measure, good design and maintenance are keys to their success. It is expected that, due to virtual elimination of sun energy on roof surfaces and resulting degradation of roof materials, that EcoRoofs will be likely found to last much longer than many traditional roof materials. As with any roof, good construction techniques are important. The City is undertaking economic analyses of life cycle costs and benefits of EcoRoofs to be able to further demonstrate their value and effectiveness to developers and the community at large.

Reference

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